A Dense and Sickly Mist from Thousands of Bog Fires: An Attempt to Compare the Energy Consumption in Slash-and-Burn Cultivation and Burning Cultivation of Peatlands in Finland in 1820–1920

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ABSTRACT

In historical research about fire-clearance husbandry in Finland the focus has been on burning of forests, while swamps and other peatlands have been neglected. I claim that this neglect is not acceptable. According to my calculations, the amount of biomass measured by energy value burned on peatlands surpassed the amount burned in slash-and-burn cultivation after the mid-nineteenth century. A comparison with other sources of carbon dioxide shows also, that burning cultivation of peatlands was by far the greatest source of carbon dioxide in Finland during the whole of nineteenth century and at the beginning of the twentieth century.

Burning cultivation of peatlands has been practised in peat-rich countries at one time or other throughout Western Europe. In these and other peat-rich countries, the inclusion of the emissions from burning cultivation could substantially alter historical carbon dioxide emission estimates.

KEYWORDS

Finland, Europe, burning cultivation, slash-and-burn, peatlands, carbon dioxide

INTRODUCTION

Fire has been used in agriculture since ancient times all around the world. Generally it was the cheapest and most effective method available for the clearance of woods, bushes and moss from the land. Another advantage was that no manure

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was needed, as the ash worked as a fertiliser and also decreased soil acidity. Historical research has concentrated on the burning of hard lands, especially slash-and-burn cultivation, while peatlands have been neglected. For example, in Stephen J. Pyne's comprehensive *Vestal Fire* the latter are only briefly mentioned, and in a recent comprehensive history of Finnish agriculture only a few pages out of thousands were dedicated to the burning of peatlands, compared to around a hundred devoted to slash-and-burn cultivation. Fifty years earlier W.G. Hoskins managed to explain the making of the English Landscape without even mentioning burning of peatlands.[1]

This article compares the biomass consumption of slash-and-burn cultivation to that of burning cultivation of peatlands in Finland, to see whether this neglect is justifiable. Finland has been chosen as a case study because it is one of the Western countries where the use of fire in agriculture lasted longest. Before the comparison, I present the general characteristics and development of both slash-and-burn cultivation and burning cultivation of peatlands, and first of all I show that burning cultivation of peatlands was practised all over Europe and North America, and was by no means a Finnish curiosity. The question remains, to what degree can my results from Finland be generalised to other peat-rich countries?

BURNING CULTIVATION OF PEATLANDS IN WESTERN EUROPE AND NORTH AMERICA

Throughout history, different methods have been employed all over Western Europe for the burning of peatlands for agricultural purposes. The Finnish professor of chemistry Pehr Adrian Gadd wrote in 1773 that peatland burning was practised to some extent in Germany and France. He wrote that even the English, who otherwise were so attentive and skilled in husbandry, were still occasionally using this method of cultivation. In 1899 Gösta Grotenfelt, a Finnish agricultural historian, wrote that he had seen the practice still current to a large extent in Sweden, Germany and Russia.[2]

In the region of Germany where peatlands are most abundant, only 25 hectares were burned in 1919, and 38 hectares in 1920. According to Antti Vesikivi, burning cultivation had, however, been practised in Germany on such a scale that it is rare to find a cultivated raised bog that has not been burned at all. He traces the origin of the burning of raised bogs to Holland, from where it spread to Germany. The Dane E. Dalgas wrote in 1881 that turf smoke often reached the East coast of Jutland: 'This *moorburning* has been a virtual nuisance in Holland and Hanover, because the smoke from thousands of bog fires produces such a dense and sickly mist, which spreads widely southwards in Germany and that has caused the creation of an "Anti-Moorbrennen-Verein" (an *Anti-Moorburning organisation*).'[3]

According to Stephen J. Pyne, two methods of peatland burning emerged; 'One imitated slash-and-burn forestry, in which paring, drying and burning occurred more or less on the site. The other mimicked charcoal, tar or potash production, in which the cut turf was gathered into piles, often covered, sometimes placed into ovens, and slowly burned; peasants then carried the ashes back to the fields.' He claims that this practice, which he calls *paring and burning*, was most widespread in Britain, which had upland bogs in abundance. In 1791, Arthur Young reported that in the fen district, 'It is scarcely possible profitably, to bring boggy, mossy, peat soils, from a state of nature into cultivation, without the assistance of fire.'[4]

According to A.T. Lucas, paring and burning was in existence in Ireland from at least as early as 1281 up until at least 1894. In Scotland, the main phase of paring and burning was in the late eighteenth and early nineteenth centuries, but it continued far into the nineteenth century. Another burning method used was *ribbing and burning* (in England they used the term *velling and skirting* for the same practice), where the main tool was the plough instead of the spade used in paring and burning. The place name *bruntlands*, common in Northeast Scotland, commemorates land brought or kept under cultivation using a burning technique. Both paring and ribbing, and paring and burning are cultivation methods that could be used on different kinds of soils, but it is apparent that a great deal of peatland was burned. [5]

The knowledge of English paring and burning methods was repeatedly transmitted from England to Sweden, from 1727, when it was first presented by Serenius, until the middle of the nineteenth century. Inspiration for burning cultivation was also distributed through translations of German textbooks, such as Albrecht Thaer's *Grundsätze der rationellen Landwirthschaft*, which was published in Swedish in 1817 and reprinted in 1846.[6]

A more likely source for inspiration, however, at least for the northern parts of Sweden, was Finnish Ostrobotnia, on the other side of the Gulf of Bothnia: Finland was part of Sweden until 1809, and climatic conditions were similar on both sides of the gulf. This can also be seen in the regional variation in the tools used: the paring spade in Southwest Sweden, and the hoe elsewhere. The English example was important, however, as its agriculture was considered the best imaginable. Therefore, the practise of burning cultivation in England also worked as an endorsement for it in Sweden. [7]

In 1749, an early Swedish critic of burning cultivation of peatlands, Carl Linné, condemned marsh swidden as twenty times worse than bad forest swidden – as a forest could be regrown twenty times before a new and as good peatland had grown. Lundequist, on the other hand, in his *Bondepraktika* from 1840, stated that deeper mires were most preferably burnt and with best success after tussocks had been chopped with a hoe. In a report from a study trip in summer 1897, the Finnish peatland cultivation counsellor E.A. Malm stated that peatland cultivators in Sweden seldom used burning methods and even then only burned

the surface. As late as 1901, and again in 1923, H. Juhlin Dannfelt gave advice for burning cultivation of peatlands, although he restricted its proper use to sphagnum-covered peatlands. However, Hjalmar von Feilitzen, from the Swedish peatland cultivation society, wrote in a letter to Antti Vesikivi that peatland burning was extremely rare in 1920, as people knew that it was harmful.[8]

Peatlands were also burned in North America. According to a study trip report written by Hugo Osvald, burning was still common in the 1920s in the cultivation of peatlands in Minnesota, Michigan and British Columbia. Fire was also used to create cranberry plantations on peatlands in New Jersey and Massachusetts.[9]

BURNING CULTIVATION OF PEATLANDS IN FINLAND

The methods of cultivation used in Finland can be divided into two types, Eastern and Western, based on the core area and the type of peatlands burned. The eastern type, based on the cultivation of wooded peatland, was an adaptation of slash-and-burn cultivation methods, and no clear line can be drawn between these two practices (this type can also be found in Kalimantan in Indonesia). The Western method could be used on treeless peatlands. By the end of the nineteenth century, the dividing line between Eastern and Western cultivation practices started to blur as treeless *sphagnum* bogs began to be cultivated in eastern Finland, following the example of Ostrobotnia.[10]

In the Western method, the cultivation process began with the ditching of the assigned peatland. After the peatland had dried for some years it was hoed or harrowed, and afterwards the twigs and peat were burned as soon as the surface had dried. Any trees were felled and their roots dug up before harrowing. Finally, rye or oats were usually sown in the ash. The hoeing or harrowing and burning were repeated for new yields until the bottom of the peatland was reached or the peatland was left to grow grass.[11]

Peatland burning is mentioned in court protocols around 1640, but it might have been practised in Finland as early as the fourteenth century. Initially it was mainly used for creating meadows, as these did not require as thorough drainage as grain cultivation. According to Gösta Grotenfelt, peatland cultivation was relatively widespread in several parts of the country during the last decades of the eighteenth century. It was most common in the peat-rich region of Ostrobotnia on the Western coast of Finland, where it compensated for the diminution of forest resources caused by slash-and-burn cultivation and tar burning. In some districts of Ostrobotnia during the 1820s and '30s, over half of the yield of some grains came from peatland cultivation. Peatland cultivation was also important in most parishes in eastern Finland.[12]

THE AMOUNT OF WOOD BURNED IN SLASH-AND-BURN CULTIVATION IN FINLAND

Slash-and-burn cultivation can be defined as a cultivation method of cutting down living trees to clear land, burning the biomass after it has dried, and planting a crop in the ashes in an appropriate season. It was a pioneering method of grain cultivation for the Finns of the Stone Age as well, as forests covered practically all dry soil and some method of clearing was indispensable.[13]

Based on estimations made during the period 1654–1861, Olli Heikinheimo has calculated that altogether slash-and-burn cultivation was practised on an area of four million hectares (8,265,502 tunnlands). With a rotation period of 30 years, as proposed by Heikinheimo, 135,000 hectares would have been burned each year.[14]

According to estimates by C.W. Gyldén around 39,200 hectares (80,000 tunnlands) of forest were *swidden* per year in the middle of the nineteenth century, consuming 1.36 million m^3 solid measure (520,000 *normaalisyltä*) of wood. In other words, 35 m^3 of wood was burned per hectare swidden. There is reason to suspect that Gyldén's estimate of the swidden area was too small, as his assessment of the state of the forests has been criticised as being too optimistic. Gyldén's estimation can however be taken as a minimum estimate of the wood burned in slash-and-burn cultivation.[15]

August Soldan estimated, mainly based on Gyldén, that 1.1 million m^3 of wood was consumed in slash-and-burn cultivation in 1862. A. Sivén estimated that 1 million m^3 solid measure (400,000 *normaalisyltä*) was burned in 1885.[16]

From 1890 onwards, I have used Heikinheimo's calculations based on the grain yields from slash-and-burn cultivation. The area of grain swidden was, according to Heikinheimo's calculations, 17,300 hectares in 1890, 7,700 hectares in 1900 and 3,800 hectares in 1910. However, as the calculations are based on the grain yield, the areas burned to create meadows are missing. To get a rough estimate of the total area burned, I have therefore multiplied Heikinheimo's estimates by 1.5. Thus, the area burned in 1890 would be 25,950 hectares. Assuming the same amount of wood burned per hectare as in Gyldén's estimate, the amount of wood consumed would be 908,250 m^3. This is close to the above-mentioned estimate by Sivén for the total amount burned in 1885.[17]

Finally, the area of land under slash-and-burn cultivation was obtained from official statistics for the years 1910, 1920 and 1923–1929. Once again, these reported areas have been multiplied by 1.5 to include areas burned to create meadows. It is also assumed that each plot was cultivated for two years. In 1930 and afterwards there are no mentions of slash-and-burn cultivation in the official statistics.[18]

I have assumed that 40 m^3 solid measure of wood were consumed per hectare burned in 1800, with a linear decline to 35 m^3 in 1850, as the quality of areas under slash-and-burn cultivation diminished due to shortened rotation periods. I

have used the constant 35 m^3 from 1850 onwards.[19] The amount of wood burned is then calculated by a simple multiplication of the area burned by the cubic metres burned per hectare. The outcome is presented in Figure 1.

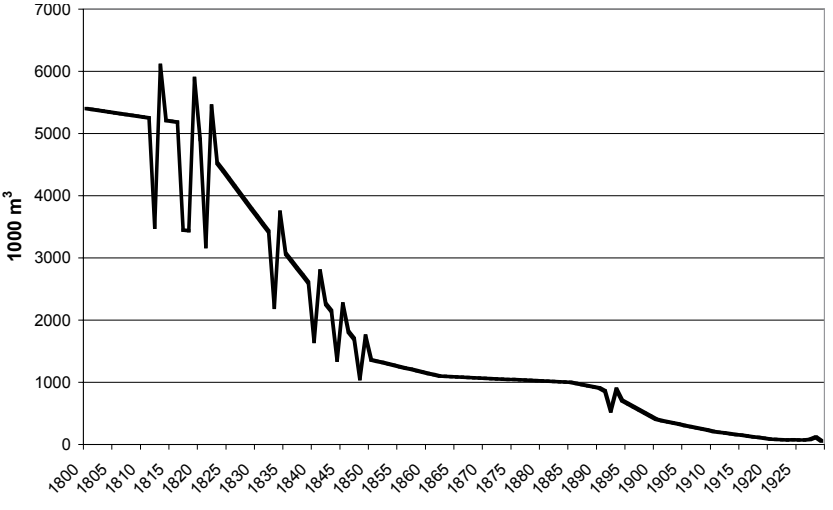

FIGURE 1. Timber burned in slash-and-burn cultivation in Finland, 1800–1929.

Due to exceptionally long and continuous rainy periods slashed areas could not be burnt in several parts of the country during the years 1812, 1817, 1818, 1821, 1824, 1828, 1833, 1840 and 1844. For these years, I subtracted one third of the wood burned according to the trend, while adding half of the subtracted consumption to the amount burned the next year.[20]

THE AREA OF PEATLAND CULTIVATION IN FINLAND

According to an official agricultural questionnaire, 433,206 hectares, or 21.5 per cent of all field cultivation, was in 1920 on peatlands. Of the areas of cultivated peatland, 393,472 hectares (90.8 per cent) were mud swamps and 39,734 hectares (9.2 per cent) sphagnum bogs. Peatland cultivation was most common in the county of Vasa in Ostrobotnia, where 146,664 hectares of peatland was under cultivation, of which 84.4 per cent were mud swamps and 15.6 per cent sphagnum bogs.[21]

The 1920 questionnaire was the first one in which soil type was recorded; previously only the total field cultivation area had been asked for. From 1901 to 1920, I have estimated that the growth of peatland cultivation was as large as

the total growth of field cultivation area. In other words, the peatland cultivation area in 1901 would have been 78 per cent of that in 1920 and the area in 1910 would have been 93 per cent of that in 1920.[22]

For the years before 1901, I have calculated the peatland cultivation area by counting backwards. The cultivation area for a particular year has been calculated by subtracting the reclaimed area that year from the cultivation area in the subsequent year. According to official statistics, 158,000 hectares were reclaimed during the period 1860–1890, while the reclaimed area per year varied from 1,600 to 9,000 hectares. According to Gabriel Rein, around 2,513 hectares of peatland were reclaimed for cultivation per year from 1847 to 1850. For the periods 1820–1846, 1851–1859 and 1891–1900, I have used Ilmari Palmén's estimate of the amount of peatland drained as a proxy for the reclaimed area, as draining is a precondition for cultivation. His estimates of the area drained range from 200 to 2,200 hectares per year. These estimates of the reclamation of peatland for cultivation are presented in Figure 2.[23]

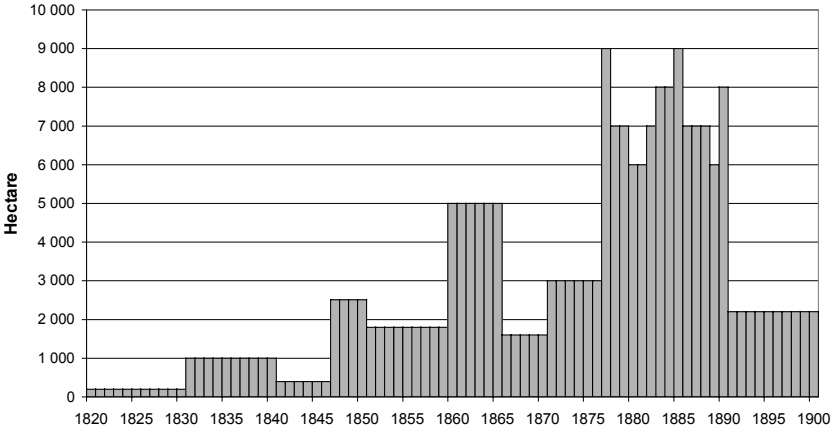

FIGURE 2. The area of peatland reclaimed for cultivation in Finland, 1820–1900.

Based on an examination of sample plots, Antti Vesikivi estimated that in Ilmajoki in Southern Ostrobotnia, 91.9 per cent of all cultivated peatland (7,800 hectares) was under burning cultivation in 1920. He completed his survey with an enquiry about the extent of burning cultivation of peatland in Southern Ostrobotnia. The total cultivation area in the sphere of operations of those 73 agricultural societies which answered the questionnaire was 214,703 hectares, of which 92,652 hectares were peatland. Of the area of cultivated peatland 79,446

hectares were mud swamp, and of that 28,450 hectares (36 per cent) were cultivated using burning methods. Sphagnum bogs made up 14 per cent, of which 12,413 hectares (94 per cent) were cultivated using burning methods.[24]

According to an enquiry from 1919, in most parishes outside of the County of Vasa in Ostrobotnia peatland burning was not practised, or was mainly used for the burning of twigs and the moss layer; in the latter cases, the intention was not to burn the peat layer. On the other hand, Vesikivi's enquiry covered more than half of the area in Vasa parish, where burning cultivation was practised to a larger degree. Therefore, I have assumed that the area of peatland under cultivation by burning in the whole country in 1920 was no more than double that in Vesikivi's survey – in other words 56,900 hectares of mud swamps and 24,826 hectares of sphagnum bogs under burning cultivation. Based on this assumption, I have estimated that across the whole country 14.5 per cent of the mud swamps and 62.5 per cent of the sphagnum bogs under cultivation were under burning cultivation in 1920.[25]

The percentage of cultivated peatland made up of sphagnum bogs in 1820 is assumed to be double that of 1920 (8.2 per cent), with a linear decrease between these years. This assumption is based on the general view that most of the mud swamps under cultivation had a sphagnum surface when taken into cultivation. The percentage of mud swamps that were cultivated by burning in 1820 is assumed to be double that in Vesikivi's enquiry from 1920 (twice 36 per cent = 72 per cent), and the percentage of sphagnum bogs is assumed to be the same as in 1820 (94 per cent). These high percentages can be borne out if one considers Arvo Soininen's argument that peatland cultivation was almost entirely based on burning well into the nineteenth century. According to the Swede H. Juhlin Dannefelt, burning was the only way to bring peatlands into cultivation in earlier periods, when there was barely enough manure for the hard lands.[26]

I have assumed a linear decline in the percentage of sphagnum bogs under burning cultivation up until 1920, in order to take into account improvements in cultivation techniques and availability of fertiliser. The percentage of mud swamps under burning cultivation is assumed to have fallen by half by 1894. The decline is assumed become steeper thereafter, as the Finnish Society for Peatland Cultivation was founded, and it started to promote 'rational' peatland cultivation methods in which the need for burning was decreased. The Society, however, considered burning cultivation combined with the use of soil improving substances to be praiseworthy on sphagnum bogs.[27]

Finally, by multiplying the area of peatland under cultivation by the estimated percentage of burning cultivation, we get the amount of peatland under burning cultivation, as presented in Figure 3.

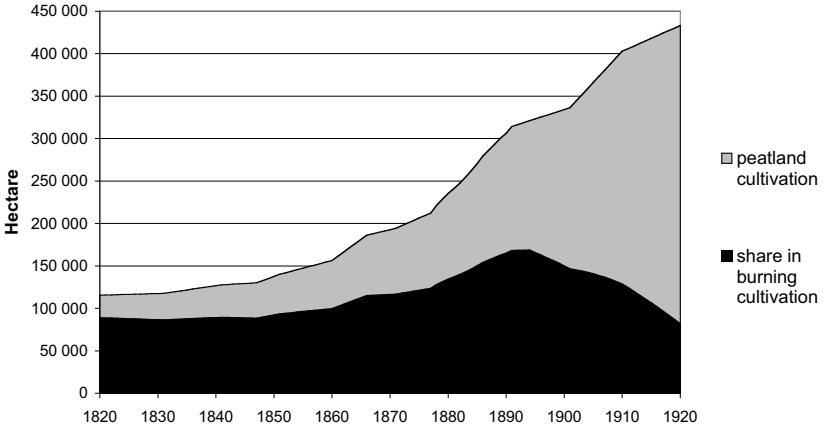

FIGURE 3. Peatland cultivation area in Finland, 1820–1920.

ENERGY CONSUMED IN SLASH-AND-BURN CULTIVATION AND BURNING CULTIVATION OF PEATLANDS

As the last step of my analysis, I have calculated the energy content of the wood and peat burned in both slash-and-burn cultivation and burning cultivation of peatlands, in order to be able to compare the consumption of natural resources.

I have assumed a seven-year rotation period for the peatlands, during which they were burned over two years. Antti Vesikivi found in his research a rotation period of six years, while J. Tengström reports a period of 8 years. Thus, I have divided the area of peatland under burning cultivation by 3.5 to get the total burned area for each year.[28]

I have assumed that 2.16 cm of the peat layer in mud swamps was burned during each burning year, and 2.99 cm in sphagnum bogs. These numbers are average values from 41 reports given in Antti Vesikivi's enquiry of the depth of the peat layer consumed during each year of burning, with a range from 0.25 to 5 cm. This might be an underestimate; according to A. E. Rautakorpi, as much as 4–5 cm of peat surface might have been burned.[29]

The energy content of peat burned in mud swamps is assumed to be 0.45 MWh/m^3 (the average energy content for *carex brown-moss peat* with humification degree 4 on the von Posts scale) and in sphagnum bogs to be 0.311 MWh/m^3 (the average energy content for *sphagnum peat* with humification degree 1–2 on the von Posts scale). In slash-and-burn cultivation, the average energy content of mixed wood 0.171 TOE per m^3 solid measure of wood is used.[30]

The result of these calculations is shown in Figure 4. The higher estimate for burning cultivation of peatlands is based on the assumption of a burning depth of 4 and 5 cm, and the lower on 2.16 and 2.99 cm.

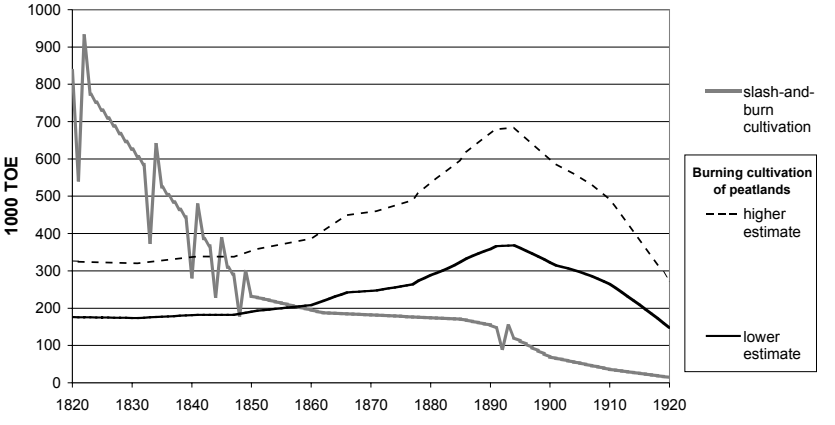

FIGURE 4. Energy consumption in slash-and-burn cultivation vs. burning cultivation of peatlands in Finland 1820–1920. 1 TOE (ton of oil equivalent) corresponds to 41.868 GJ.

Energy consumption in slash-and-burn cultivation had already started to decline by the beginning of the nineteenth century. As rotation periods shortened, less timber was burned and less ash was produced, which led to diminishing yields. The final countdown for slash-and-burn cultivation began in the mid-nineteenth century as a result of the growing sawmill industry. This increased the value of timber and toughened the attitude of forest owners and the authorities towards slash-and-burn cultivation. Between 1859 and 1861, the sawmill industry was released from production restrictions that had prevailed since the seventeenth century, and the ban on steam-driven sawmills was relaxed.[31]

As the rapidly growing sawmill industry expanded, its timber purchases deep inland increased and the price for standing timber rose, it became more profitable to sell timber instead of engaging in laborious slash-and-burn cultivation, or renting the forests to the landless population for slash-and-burn cultivation. By the end of the nineteenth century slash-and-burn cultivation had become insignificant, although it was sporadically practised in the early decades of the twentieth century.[32]

During the whole of the nineteenth century, the energy consumed in burning cultivation of peatlands increased along with the decline in slash-and-burn cul-

tivation, as the peatlands replaced diminishing swidden opportunities. After the mid-nineteenth century, the amount of biomass measured by energy value burned on peatlands surpassed the amount burned in slash-and-burn cultivation.

By the end of the eighteenth century, a few writers were already drawing attention to the excessive burning of peatlands. In 1773, Pehr Adrian Gadd wrote in his agricultural handbook that, where the population is small and wealth minor, and where there is a large supply of peatland, the easiest and cheapest way to cultivate marshland is by burning. He remarked, however, that this resulted in the destruction of large areas of fertile land for the sake of a few harvests, which would be unlikely to endear the farmers to their descendants.[33]

As the area of peatland burned increased in the nineteenth century, an increasing amount of attention was paid to associated malpractices, such as burning peatlands to the bottom. The Finnish Society for Peatland Cultivation campaigned for 'rational' cultivation methods, where burning was replaced with the use of sand, clay and fertilisers. Lack of fertilisers and a drop in yields during a transition period of up to ten years, because the bacterial strain had been destroyed by burning, postponed the abandonment of burning methods in cultivation of peatlands. Finally, at the beginning of the twentieth century, the amount of biomass burned in the cultivation of peatlands started to decline as well.[34]

DISCUSSION AND CONCLUSIONS

The scarcity of sources to rely on has forced me to make rough generalisations when estimating the amount of peat burned in burning cultivation of peatlands. The single biggest source for possible errors is the estimate of the depth of the peat layer burned. The estimates used in this calculation (2.16 and 2.99 cm, and 4 and 5 cm) can be seen as rather modest, as according to one source as much as 7.5 cm of the peat layer was burned. On the other hand, E. G. Svinhufvud reports a burning depth as little as 1.1–1.3 cm in his burning experiments, but they were carried out during a rainy summer. Neither have I taken into account the fact that occasionally the peatlands were burned to the bottom. Altogether, it is most likely that I have underestimated the amount of peat burned.[35]

I argue that leaving matters uncalculated due to scarcity of sources can be even more misleading. For slash-and-burn cultivation, some estimates have been made of the wood consumption for various single years. No attempts to calculate the amount of peat burned in burning cultivation of peatlands have been made before. There is also much more statistical material and many more historical documents available for slash-and-burn cultivation. As proposed in the introduction, this has led to the neglect in historical research of burning cultivation of peatlands as compared to slash-and-burn cultivation. This is a major shortfall, especially for environmental history.

The reason for the difference in the number of documents available might be that, unlike the forests, there was no concern that the peatlands might run out. On the contrary, clearing of peatlands was seen as an important issue, as peatlands were seen as frost nests. For example, Esaias Wegelius wrote in his dissertation in 1763 that Finland's large peatlands were a major reason for our short summers and long cold winters. He drew this conclusion from the fact that Quebec in Northern Canada was much colder than Amsterdam in Holland, although the former is 5 degrees south of the latter. According to him, the reason was that there were many peatlands in Northern America, whereas they had been ditched and transformed into fertile land in Holland. Wegelius also considered the fog rising from the peatlands a health risk, causing pneumonia, coughs, throat diseases and fever.[36] Two hundred years later, in 1959, Dr. Olavi Huikari claimed that there was a clear connection between the proportion of peatlands and the amount of unemployment in different parts of Finland.[37]

Total carbon dioxide emissions from burning cultivation of peatlands would be, according to the lower estimate presented in Figure 4, around 110 million tonnes for the period 1820–1920.[38] This is about 10–30 times higher than emissions from present peatland fields during a time span of hundred years. A comparison with other sources of carbon dioxide shows that burning cultivation of peatlands was by far the biggest source of carbon dioxide in Finland during the whole of the nineteenth century and at the beginning of the twentieth century. Net emissions from slash-and-burn cultivation and other use of wood are assumed to be zero, as the forests have grown back, binding the released carbon again.[39]

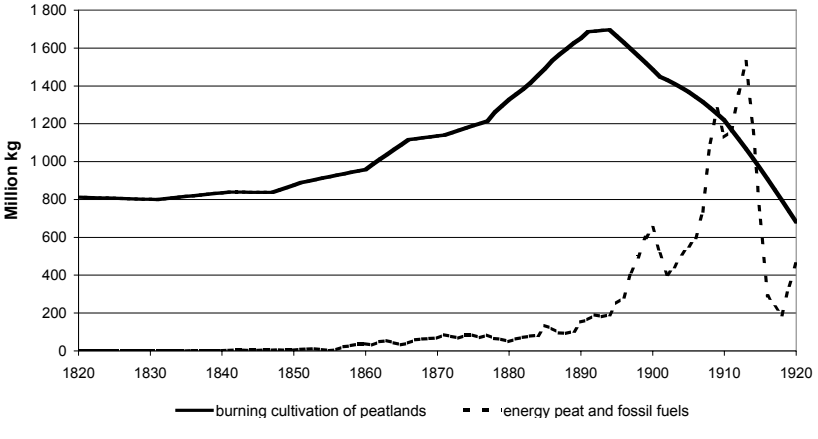

FIGURE 5. Carbon dioxide emissions from burning cultivation of peatlands vs. emissions from energy peat and fossil fuels 1820 – 1920. Source: Jan Kunnas, The Environmental Kuznets-curve-hypothesis and Air Pollution Related to Energy Production in Finland (Master's Thesis University of Helsinki, Faculty of Social Sciences, Department of Economics).

Burning cultivation of peatlands has been practised in peat-rich countries at one time or other throughout Western Europe. In these countries and other peat-rich countries, the inclusion of the emissions from burning cultivation could alter historical carbon dioxide emission estimates substantially.

Compared with present emissions of carbon dioxide, the emissions from burning cultivation of peatlands in Finland are relatively small. Even at their height, the emissions from burning cultivation of peatlands were only around one thirtieth of present emissions from peat and fossil fuels. Present carbon dioxide emissions from the burning of peat alone are around four times greater than the emissions from burning cultivation of peatlands at its height.[40]

While old swidden areas have been reforested, the marks of burning cultivation of peatlands are still clearly visible in the Finnish landscape. As a memorial to this practice we have large field plains, especially in Southern Ostrobotnia, which are nowadays officially classified as valuable landscapes. Altogether around 700,000 hectares of peatland have been transformed into arable land in Finland. In a large portion of these lands the peat has completely disappeared through combustion or decay.[41]

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NOTES

[1] Nils-Arvid Bringéus, *Brännodling – En historisk-etnologisk undersökning* (Lund: CWK Gleerup, 1963), 13 [with an English summary]. Stephen J. Pyne, *Vestal Fire – An Environmental History, Told through Fire, of Europe and Europe's Encounter with the World* (Seattle and London: University of Washington Press, 1997). *Suomen maatalouden historia I–III* (Helsinki: Suomalaisen Kirjallisuuden Seura, 2003–2004). William George Hoskins, *The Making of the English Landscape* (London: Hodder and Stoughton 1988) first printed in 1955.

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[10] Grotenfelt, *Det primitiva jordbrukets metoder*, 213. M.R. Dove, *Swidden Agriculture in Indonesia – The Subsistence Strategies of the Kalimantan Kantu'* (Berlin: Mouton Publishers, 1985), 83, 189–94.

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[12] Armas Lukko, *Etelä-Pohjanmaan Historia III. Nuijasodasta Isoonvihaan* (Vaasa: Etelä-Pohjanmaan Historiatoimikunta, 1945), 99–104; K.R. Melander, 'Några uppgifter om äldre tiders kärrodling i vårt land', *Historisk tidskrift för Finland. Årg. 7.* (Helsingfors, 1922), 24*;* Grotenfelt, *Det primitiva jordbrukets metoder*, 205–10; Arvo M. Soininen, *Vanha maataloutemme, Maatalous ja maatalousväestö Suomessa perinnäisen maatalouden loppukaudella 1720-luvulta 1870-luvulle* (Helsinki: Suomen historiallinen

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[15] C.W. Gyldén, *Handledning för skogshushållare i Finland* (Helsingfors, 1853), 8. Jouni Aarnio, *Kaskiviljelystä metsätöihin, Tutkimus Pielisjärven kruununmetsistä ja kruunumetsätorppareista vuoteen 1910* (Joensuu: Joensuun yliopiston maantieteen laitos, 1999), 93. Ari Perälä, 'Kronans skogshushållning och frigivningen av sågindustrin i Finland 1861', *Historisk tidskrift för Finland* (4/1987), 643.

[16] Aug. F Soldan, *Suomen tervanpoltosta ja kuinka se olisi parannettava* (Helsinki, 1862), 38. Calculation by A. Sivén presented in A.g. Blomqvist, *Metsänhoidon kansallistalous* (Helsinki: J. Simeliuksen perillisten kirjapaino osakeyhtiö, 1862), 85. See also V. Pöntynen, 'Aikaisemmat Suomen puun käyttöä selvittelevät tutkimukset', in Eino Saari, *Puun käyttö Suomessa,* Metsätieteellisen tutkimuslaitoksen julkaisuja 14.1. (Helsinki, 1934), 2, 4.

[17] Olli Heikinheimo, *Kaskiviljelyksen vaikutus Suomen metsiin*, 54.

[18] 8,370 hectares in 1910, 3,315 in 1920, 2,868 in 1923, 2,876 in 1924, 2,716 in 1925, 2,773 in 1926, 3,162 in 1927, 4,549 in 1928 and 2,012 hectares in 1929. Suomen virallinen tilasto, osa III: maatalous (Helsinki: valtioneuvoston kirjapaino, 1910–1930).

[19] Gyldén, *Handledning för skogshushållare i Finland*, 8.

[20] Gösta Grotenfelt, *Suomalainen peltokasviviljelys*, *jälkimmäinen osa* (Helsinki: Otava, 1922), 30.

[21] *Maataloustiedustelu Suomessa vuonna 1920* (Helsinki: valtioneuvoston kirjapaino, 1924).

[22] Hannes Gebhard, *Tilastollinen tutkimus yhteiskunta-taloudellisista oloista Suomen maalaiskunnissa v. 1901. Osa III, Viljellyn maan ala ja sen jakautuminen* (Helsinki: Tilattoman väestön alakomitea, 1908), 51.

[23] Bidrag till Finlands officiela statistik, Finlands officiella statistik del II, 1860–1890. Gabriel Rein, *Statistisk teckning af storfurstendömet Finland. Förra Delen*. Tredje Omarbetade upplagan. (Helsingfors: Wasenius & Komp. Förlag, 1853), 86. Ilmari Palmén, Suonkuivatustyöt Suomessa XIX vuosisadalla. Suomen suoviljelysyhdistyksen vuosikirja 1903, kolmas vihko (Helsinki, 1904), 189–254.

[24] Vesikivi, *Suonpolttoviljelyksen nykyinen laajuus Etelä-Pohjanmaalla*, 19.

[25] E.F. Simola, *Suomen uutisviljelystavoista* (Helsinki: Asutushallitus, 1921), 99, appendixes 40–49. Vesikivi, *Suonpolttoviljelyksen nykyinen laajuus Etelä-Pohjanmaalla,* 12, 52–4.

[26] E.A. Malm., *Suomen suoviljelysyhdistyksen vuosikirja* 1904, 212. Soininen, *Vanha maataloutemme*, 138–9. H. Juhlin Dannfelt, *Handbok i Jordbrukslära*, 143.

[27] *Suomen suoviljelysyhdistyksen vuosikirja* 1896, 25.

[28] Vesikivi 1922, *Suonpolttoviljelyksen nykyinen laajuus Etelä-Pohjanmaalla*, 26; Jacobus Tengström, *Försök till lärobok i landthushållningen för finske bonden* (Åbo 1803).

[29] Vesikivi, *Suonpolttoviljelyksen nykyinen laajuus Etelä-Pohjanmaalla*, 26. Erkki Huokuna, *Sata vuotta suotutkimusta ja viljelyneuvontaa, Suoviljelysyhdistys ry - Mosskulturföreningen rf 1894–1994* (Mikkeli: 1994), 12.

[30] Markku Mäkilä, *Suon energiasisällön laskeminen turpeen ominaisuuksien avulla*. Tutkimusraportti 121 (Espoo: Geologian tutkimuskeskus, 1994) [with an English summary].

[31] Ari Perälä, 'Kronans skogshushållning och frigivningen av sågindustrin i Finland 1861', *Historisk tidskrift för Finland* årg. 72 no 4 (1987), 628, 631.

[32] For example Axel Steensberg reports his visit to a 6 ha large burning in Finland in April and May 1949 [*Fire-Clearance Husbandry*, 111–15] and Pentti Kallio presents a couple of examples of burning cultivation from as late as in the 1960s and 1970s ['Neljän tuulen lakeus', in Jussi Klemola et al. (eds.) *Kauhajoen metsien ja soiden kirja*. (Kauhajoki: Lions Club Kauhajoki, 1999), 136–7].

[33] Gadd, *Försök till en systematisk inledning i Swenska landtskötselsen*, 260.

[34] Vesikivi, *Suonpolttoviljelyksen nykyinen laajuus Etelä-Pohjanmaalla*, 29–30; Arthur Rindell, Suomen Suonviljely-yhdistyksen vuosikirja 1920 (Helsinki: 1920), 66–7; and 'Tiedonantoja Suomen suoviljelysyhdistyksen koetoiminnasta', *Suomen Suonviljely-yhdistyksen vuosikirja 1914* (Helsinki, 1914), 53–98.

[35] Signature L.H., 'Hiukan maatalouden historiaa, Etelä-Pohjalaista suon polttoviljelystä 1830-luvulla.' *Maatalous* (1920), 177. E.G. Svinhufvud, *Suon polttoviljelyksen vaikutusten selvittelyä*. Tieteellisiä julkaisuja N:o 10 (Helsinki: Suomen suoviljelysyhdistys, 1929) [Referat in deutscher sprache].

[36] Gust. Gabr. Hällström, 'Afhandling om Nattfrosterna i Finnland, Till svar på Kongl. Finska Hushållningssällskapets d. 2 Nov. 1801 utgifna prisfråga.', *Kongl. Finska Hushållningssällskapets handlingar, Andra tomen* (Åbo, 1807), 75–153. Esaias Wegelius, *Tankar om nödwändigheten at utdika och upodla kärr och mossar i Finland* (Aboae, 1763).

[37] Olavi Huikari, 'Pohjanmaan alityöllisyysalueella suoritetun tutkimuksen tuloksia', *Metsätaloudellinen aikakauslehti* 1959, 43.

[38] Emissions have been calculated with the assumption that 4605.48 kg of carbon dioxide would be released per TOE of peat burned.

[39] Patrick Crill, Ken Hargreaves and Atte Korhola, *The Role of Peat in Finnish Greenhouse Gas Balances* (Helsinki: Ministry of Trade and Industry, 2000). Timo Myllyntaus and Timo Mattila, 'Decline or Increase, The Standing Timber Stock in Finland, 1800–1997', *Ecological Economics* vol. 41 no. 2 (2002), 271–88.

[40] *Statistical Yearbook of Finland 200*. (Helsinki: Statistics Finland, 2003).

[41] Maisema-aluetyöryhmä, *Maisema-aluetyöryhmän mietintö osa I*, Mietintö 66/1992 (Helsinki: Ympäristöministeriö, Ympäristönsuojeluosasto, 1993), 13. E. Lappalainen and P. Hänninen, *Suomen turvevarat* [The peat reserves of Finland], Geological Survey of Finland. Report of Investigation. (Espoo, 1993).